REMARKS

Claims 1-9, 12-15, 17-30, 33, 38, 39, 42, 49-55, and 57-73 will be pending upon entry of the present amendment. Claims 1, 14, 26, and 28 are amended and new claims 66-73 are submitted herewith. No new matter has been added to the application.

Applicants thank the Examiner for indicating the allowability of claims 18-25, 29, 30, and 33, and of the subject matter of claims 4 and 55.

The amendments to claims 1, 14, 26, and 28 are not made to overcome prior art, but, in the case of claim 1, to remove extraneous text, and, in claims 14, 26, and 28, to use language that conforms to language used in new claims that depend from claim 14.

New claims 66-73 are fully supported by the specification. In particular, support can be found beginning at page 27, line 28. The subject matter of these claims will be discussed in more detail following the remarks related to the rejected claims.

Summary of Rejections Under 35 U.S.C. §§ 102 and 103

Claims 9, 38, 49, 51, and 60-65 are rejected under 35 U.S.C. §103(a) as being unpatentable over Sato et al. (U.S. Patent 5,305,429, hereafter *Sato*) in view of Guy et al. (U.S Patent 6,879,315, hereafter *Guy*); claims 50 and 55 are rejected under 35 U.S.C. §103(a) as being unpatentable over Sato in view of Guy and Matsumoto (U.S. Patent 6,587,749); claims 12, 13, 17, 39, 42, 52, 54, and 59 are rejected under 35 U.S.C. §103(a) as being unpatentable over Sato in view of Guy and Stork et al. (U.S Patent 6,104,380, hereafter *Stork*); claim 53 is rejected under 35 U.S.C. §103(a) as being unpatentable over Sato in view of Guy, Stork, and Matsumoto; claims 1-3, 57, and 58 are rejected under 35 U.S.C. §103(a) as being unpatentable over Sato in view of Guy and Massie et al. (U.S Patent 5,587,937, hereafter *Massie*); claims 5-8 14, 15, 26, and 28 are rejected under 35 U.S.C. §103(a) as being unpatentable over Sato in view of Guy, Massie, and Stork;

In the discussion that follows, when a specific passage of a U.S. patent is cited, it will be indicated by a column number separated from a line number by a colon, e.g., 4:22, indicating column 4, line 22.

Claim 9 recites, in part, "a plurality of tool translation effecter devices, each having coupled thereto a second end of a respective one of the plurality of cables such that, as the attachment point moves relative to that tool translation effecter device, the cable coupled thereto is retracted or paid out accordingly, each tool translation effecter device configured to selectively vary an active tension on the cable coupled thereto and to meter the cable as it is retracted and paid out." A combination of Guy with Sato fails to teach or suggest these limitations of claim 9 for a number of reasons. First, such a combination is inappropriate because it would change the principle of operation of the Sato reference. Sato teaches a system that employs a plurality of lines 10-13 that are each coupled at a first end to Sato's instruction point P, extend over respective pulleys 38 at fixed points, and are coupled at their second ends to respective weights (3:59-65, Figures 3 and 4). A gripping device (44-48) is provided to apply drag to each line. Sato states that "[an] object of the invention is to provide a three-dimensional input apparatus which can operate a virtual object <u>by feeding back a drag</u> in the case of coming into contact with a virtual object stored in a computer" (2:7-10, emphasis added). Sato also discusses tension control, stating that "to stably hold the instruction point 10 at an arbitrary point in the three-dimensional space, strictly speaking, tensions of the lines 12-1 to 12-4 to hold the instruction point 10 must be controlled in accordance with the position of the instruction point 10. However, actually, <u>it is sufficient to attach the weights</u> 40 to the tips of the lines 14-1 to 14-4 and to equalize the weights of the respective weights of the lines 14-1 to 14-4." Thus, Sato rejects the concept of actively controlling tension on the lines either for the purpose of resisting movement of its instruction point, or for stable holding of the point.

For its part, Guy employs a number of articulated arms, or elements, that are rotatable with respect to each other at "powered axes," which are driven by actuators, i.e., motors, to provide haptic feedback and control (4:26-58, 13:11-17). The relative angles of the elements change when a user moves Guy's stylus element 100. The value of each angle is derived from a signal from an encoder coupled to each respective actuator, and the position of the stylus is determined from the angles of each arm (abstract, 12:64-67). The Examiner argues that it would have been obvious to combine Guy with Sato to provide variable active tension in the lines. Applicants respectfully disagree. Sato specifically rejected the use of active, i.e.,

controlled tension, preferring a passive system, as demonstrated by the passages quoted above. The principles taught by Sato center around a haptic system that does not employ active control, but that, according to its disclosure, provides satisfactory results without such elements. The proposed combination would change Sato's principle of operation, and is therefore inappropriate. Further discussion relative to this question can be found, for example, in the MPEP at § 2143.01, VI ("[i]f the proposed modification or combination of the prior art would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render the claims *prima facie* obvious").

Second, Sato teaches away from a combination with Guy. As noted above, Sato rejects active control devices, like that provided by Guy's actuators and cables, etc., in favor of a passive system using weights and drag, thus teaching away from the proposed combination.

Third, one of ordinary skill in the art would not be motivated to combine the references as suggested, either on the basis of the teachings of the references themselves, or simply by common sense. Sato uses a plurality of lines, each connected to a single instruction point, to hold and locate the point in space. In contrast, <u>none</u> of Guy's cables are attached to its operating point, i.e., the point that is moved by the user, nor are they attached to any other common point. Signals from Guy's encoders are used to track the relative angles of its elements, not the length of its cables, and the position of its operating point is derived from the angles, not the cable lengths. The algorithms used by Sato to determine the position to its instruction point would be useless to Guy because Guy has no direct analog to Sato's lines, nor vice-versa: Guy does not disclose the math it uses to locate its point, but such equations would offer nothing of value to Sato. In the recent KSR decision (*KSR Intern. Co. v. Teleflex Inc.*, 127 S.Ct. 1727, 82 U.S.P.Q.2d 1385 (2007)), the court notes, with regard to combining references under § 103, "a court [or an Examiner] must ask whether the improvement is more than the predictable use of prior art elements *according to their established functions*. *Id*., at 1740 (emphasis added). The established function of Guy's actuators, capstains, and cables is to rotate various elements with respect to each other. In each case, the respective actuator powers rotation in both directions, i.e., clockwise and counterclockwise, and is entirely independent of the operation of the other actuators and elements. If those actuators were placed in Sato's system to apply tension to

Sato's lines, the actuators would affect the instruction point in a linear direction, would only be able to apply force in one direction of rotation, and would all be interrelated in operation, i.e., retraction of one line by one actuator would require that other lines be permitted by other actuators to unspool. These are not the established functions of Guy's elements. There is clearly no motivation to combine the references.

Fourth, the limitations of claim 9, which recites, in part, "a plurality of … cables, each cable coupled at a respective first end to the attachment point; and a plurality of tool translation effecter devices, each having coupled thereto a second end of a respective one of the plurality of cables such that, as the attachment point moves relative to that tool translation effecter device, the cable coupled thereto is retracted or paid out accordingly," are not predictable in view of the combination of Guy with Sato. As noted above, Guy's actuators operate independently of each other, and provide for both positive and negative forces. In contrast, if Guy's actuators were used in Sato's system, each would be limited to applying force in only one direction, and they would be required to operate in coordination with each other to properly apply tension to position the point and prevent lines from going slack. Sato does not provide any teaching regarding such coordination, because it has no use for such. Sato does not use actuators. Guy can only teach operation of its disclosed system and configuration, and the operation it teaches is inadequate for control in Sato's configuration. Determining and coordinating torque to be applied to actuators in the proposed configuration is not trivial, nor obvious. Thus, one of ordinary skill could not predict the outcome of the proposed combination of references.

Finally, even if it were appropriate to combine the references, such a combination would fail to teach or suggest all the limitations of claim 9, which recites "a plurality of tool translation effecter devices, <u>each having coupled thereto a second end</u> of a respective one of the plurality of cables." As shown in Sato's Figure 3, the second ends of its lines are not coupled to tool translation effecter devices nor to any other analogous device, but instead to weights that hang below the pulleys 38. For its part, each of Guy's cables is attached at a first end to an element, passes a few turns around a capstain, and is then attached at a second end back to the same element. This is shown in a number of Figures. For example, Figure 2A shows a

schematic representation in which the cable is attached at both ends to the ground surface 50 (5:16-19). Figure 2B shows a hub portion of element 14, with a cable 148 that is coupled to the hub at a first location 150a, passes around a capstain 156, and is then anchored again to the hub by a spring at location 150b (6:4-12). The spring 154 and clutch post 152 serve to hold tension in the cable, to prevent backlash, and do not contribute to the active control of the system, which is controlled by operation of the capstain. Similar arrangements are described with reference to Guy's Figures 2C (6:21-29) and 2D (6:50-56). Because neither reference, individually, teaches or suggests attaching the second end of a cable to a translation effecter device, the combination cannot be relied upon to teach that limitation of claim 9.

For at least the reasons laid out above, claim 9 is allowable over a combination of Guy with Sato.

Although their respective scopes differ from that of claim 9, claims 38, 49, 51, and 60-65 are allowable for many of the reasons outlined above with respect to the allowability of claim 9.

Furthermore, inasmuch as all of the remaining rejections rely on the combination of Sato, identically modified by Guy, to teach at least some of the respective limitations, which are not taught by the other cited references, those rejected claims, including independent claims 1, 12, 29, 38, and 62, are also allowable, for some or all of the reasons outlined above.

Turning now to the new claims 66-72, a discussion of the subject matter of these claims can be found in the specification beginning at page 23, line 11 and extending through most of page 28. For the purpose of claiming this subject matter, a number of standard mathematical terms are used, which should be construed accordingly. The terms *sum*, *difference*, and *product* refer to the values resulting, respectively, from addition, subtraction, and multiplication operations. *Optimization* refers to a class of mathematical problems in which one seeks to minimize or maximize an *objective function* by selecting the value(s) of one or more variables. *Force vector* refers to a force operating on an object in a defined direction at a defined magnitude.

While the terms defined above and the subject matter disclosed in the specification, in particular that of page 28, will be readily understood by those of ordinary skill in

the art, the following plain-language discussion is provided to show the relationship between the language of the claims and the disclosed embodiment, and to distinguish the claimed subject matter over the art of record.

Equation 13, from page 28 of the specification, is reproduced here below:

$$J = (A\tau - f) + \alpha[\tau]^2$$
$$\text{for}$$
$$\min[J]^2 \Rightarrow 0$$

Equation 13 is an example of an optimization problem, in which the objective function J is to be minimized by adjusting the value of τ. A represents a matrix that shows the vector along which force is applied by each of the cables of that embodiment. Because each cable can only apply force directly along the line of the cable, the vector for any given cable, as represented mathematically in the matrix in the X, Y, and Z planes, will also correspond to the actual position of that cable relative to the tool or attachment point, in the same planes. These values are derived from the position of the tool relative to the anchor points of the cables, as determined from the cable lengths (see the discussion on determining the position of the tool, beginning at 23:11). τ is a scalar that displays the magnitude of force applied to each cable. Thus, a force vector for each cable is expressed in the matrices A and τ. The force vectors applied by each of the cables act collectively to exert a single force vector on the tool that can be determined mathematically from the values of the individual force vectors of the cables, and that is expressed as the product $A\tau$. This is the force vector that is actually applied to the tool.

f is a matrix expressing a target or ideal force vector to be applied to the tool, as computed by the system on the basis of the position of the virtual or remote tool relative to other elements in its environment. In the absence of real-world limitations, f is the force vector that would always be applied to the tool.

The difference between $A\tau$ and f represents the difference between the force vector that is actually applied to the tool and the target force vector that the system calculates as appropriate or ideal. This will be a non-positive value according to the equation 13. In other words, the force that is actually produced at the physical tool should not be greater than the force computed by the system. The closer these two values are to each other, the smaller will be the

difference ($A\tau$ -f). Thus, this value can also be thought of as the degree of error between the target force vector and the actual force vector.

Given the goal of minimizing the value of J to be close to or equal to zero, it can be seen that the first term of the equation – ($A\tau$ -f) – should be about equal to the second term – $\alpha[\tau]^2$ – and of opposite sign; if one is positive, the other should be negative. In the present example, $[\tau]^2$ cannot be a negative number, and α is also given as a positive number (0.1, at 28:11), meaning that the second term, at least according to this embodiment, is positive. Thus, the first term will always be non-positive.

The specification suggests a value of 0.1 for α, so it can be seen that the value of $\alpha[\tau]^2$ will be very small as long as τ remains low, but will rise exponentially as τ increases. Because τ appears in both sides of the equation, this introduces a kind of feedback condition into the equation. As τ increases, the second term increases to a much greater degree, which requires a greater difference, or error, in the first term, meaning that τ is reduced to increase the difference. Thus, the degree to which error in the actual representation of the target force vector is tolerated increases as the actual force presented increases. The coefficient α serves to stabilize response in the system to small changes in τ.

The advantages of this system can be illustrated with an example. A number of disclosed embodiments employ four cables coupled at respective anchor points that define a tetrahedron, as illustrated in Figure 2. If a target force vector were simply calculated then sent to the motors coupled to the cables, the system would operate properly as long as the tool remained within the area defined by the sides of the tetrahedron. However, if the tool were to pass outside the boundaries of the tetrahedron, the system would not be able to apply force in a vector extending away from the tetrahedron, because all of the motors and cables would be on the wrong side of the tool. The system might attempt to apply negative forces to the cables, i.e., to push against the tool to render the correct force vector, which would result in the spools unwinding the cable. Even if the system did not crash, it would be unable to provide any reasonable representation of the haptic environment. It might be possible to use a different calculation for force outside the tetrahedron, but there would very likely be a perceptible transition at the boundary. In contrast, the disclosed process allows a smooth transition through

the boundary, with gradual and often imperceptible distortions in haptic feedback as the tool moves further from the interior of the tetrahedron. This enlarges the available workspace well beyond the boundaries. An additional advantage is a reduction in average motor output or duty cycle. The motors are less frequently driven to extremely high torque levels than would otherwise occur, especially when the tool is near a border of the tetrahedron, reducing wear on the motors.

Turning now to the art of record, Applicants are unable to find any reference that teaches principles such as those disclosed in the present application with regard to determination of force vector. For example, Massie provides a number of elements or conditions that affect the determination of the appropriate force signal (see, for example, 23:46-50, 23:65-24:5, 24:25-38, and 24:51-65), but these determinations are all analogous to determining the target value. Once these values are determined, they are simply "sent to the motors so that the user feels the appropriate force," (24:3-4) or "transmitted to the user apparatus" (24:64). There is no discussion or consideration of alternative methods.

The system disclosed in the Sato reference cannot apply a linear force on its lines, but can only grip them with brakes. Thus, Sato does not attempt to apply a force vector to its instruction point. The equations 1-5 that are disclosed are for the purpose of finding the position of its instruction point and for defining objects in its virtual space. With regard to collisions in its space, Sato states that, to represent a collision with a hard object, "it is sufficient to completely stop the variable length operations of the lines …" (6:55-57), and to represent a collision with an object that deforms or moves, "it is sufficient to reduce the degree of limitation of the variable length operation" (6"59-60). Sato is silent with respect to selecting values of force to be applied to its lines. The remaining references relied upon in the Office Action appear to be entirely silent regarding calculation of force vector. Accordingly, claims 66-72 are not anticipated or made obvious by the art of record, and are therefore allowable.

In light of the above amendments and remarks, Applicants respectfully submit that all pending claims are allowable, and therefore request that the Examiner reconsider this application and timely allow all pending claims. Examiner Beck is encouraged to contact Mr. Bennett by telephone at (206) 694-4848 to discuss the above and any other distinctions between

the claims and the applied references, and to address any informalities that may remain unresolved.

The Director is authorized to charge any additional fees due by way of this Amendment, or credit any overpayment, to our Deposit Account No. 19-1090.

Respectfully submitted,

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